SEEKING FIRE AND HUMAN IMPACT IN THE ROCKY MOUNTAINS: PROSPECTING IN MONTANA AND NEW MEXICO

Final Report
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**SEEKING FIRE AND HUMAN IMPACT IN THE ROCKY MOUNTAINS:
PROSPECTING IN MONTANA AND NEW MEXICO**

a joint venture agreement between the USDA Forest Service Rocky Mountain Research Work Unit 4853

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Introduction

This report details three trips made to New Mexico and Montana in the summer of 2004. The aim of this fieldwork was to identify locations with stratified natural deposits containing evidence of burning events and variations in cycles of erosion and *in situ* soil development for use in paleoclimate and fire frequency reconstruction. Study areas were sought in different landscape positions within the two regions. In New Mexico, the dry downcut riverbeds (*arroyos*) typical of this landscape reveal deep stratigraphic deposits that can be visually surveyed for evidence of fire within the arroyo walls. Criteria for suitable locations in New Mexico were based on previous research conducted by R. Periman, C. French, J. Boast and others in the Rio Puerco drainage system near Cuba, New Mexcio (French **2002,2003, 2tc.**). Additional sites in New Mexico were assessed in the Cibola National Forest Magdalena District and the Sevilleta National Wildlife Reserve-LTER in central New Mexico. Preliminary sampling was conducted at these two new sites.

In addition, several regions of western Montana were investigated within the Lolo, Deerlodge and Beaverhead National Forests as well as the Swann Valley north of Missoula. In contrast to the arid arroyos of New Mexico, peat deposits are the focus on Montana investigations as peat wetlands can be excellent repositories of palaeo-environmental data such as pollen and charcoal. Several suitable sampling locations were investigated in Montana and preliminary samples were collected at Copper Creek in the Deerlodge National Forest as detailed by French (2004).

2004 EXPLORATIONS

Rio Puerco

Following successful investigations that identified several meters of stratified undisturbed deposits in the Arroyo Tapia tributary of the Rio Puerco in prior years an attempt was made to gain access to a complete sequence in high arroyo walls by using an industrial lift. However, the topography defeated the capacity of the rig and our initial attempts were unsuccessful.

In a subsequent reconnaissance trip with C. French, sample locations with excellent potential for intensive sampling were identified in other tributaries of the Rio Puerco (see French 2004).

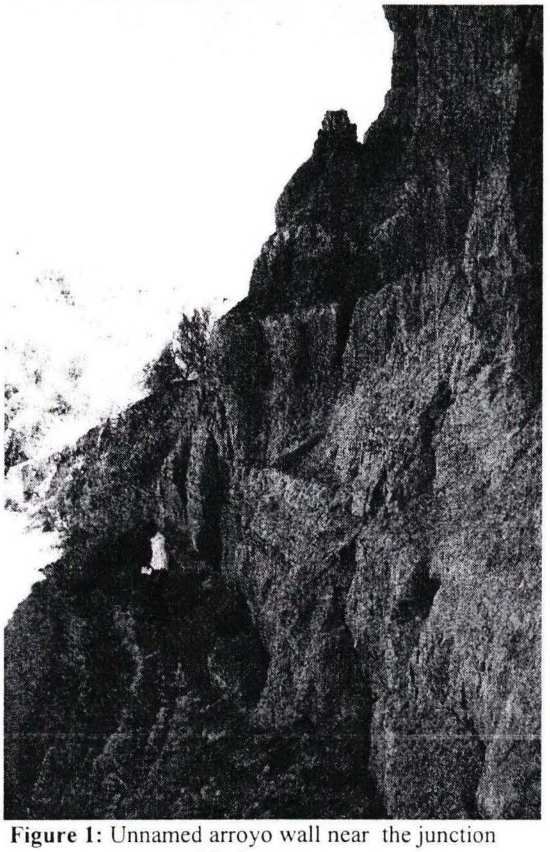


Figure 1: Unnamed arroyo wall near the junction with the Rio Puerco.

In brief, it is apparent that the Rio Puerco landscape has seen three cycles of stabilization with concomitant floral development followed by episodes of rapid destabilization, erosion and fire.

An unnamed arroyo shows the clearest sequence identified to date with three distinct erosion/standstill events (Figure 1). Charcoal deposits are clearly visible in the middle and upper events. The lower stabilization zone appears homogenized in the field but may yield micro-charcoal for AMS dating.

It was proposed that future sampling include parallel core drilling for uncontaminated bulk and radiocarbon samples and judgmental sampling for soil thin sections (French 2004).

Sevilleta National Wildlife Refuge

The Sevilleta National Wildlife Refuge is both a Long Term Ecological Research Station and University of New Mexico Research Field station. The Sevilleta provides a controlled research environment with the opportunity for collaboration with researchers investigating other aspects of climate, flora and fauna in the region (http://sev.lternet.edu/). As a refuge, this region is protected from the heavy grazing that is endemic to the riparian areas of New Mexico. In addition, controlled burns of the high desert vegetation by other research teams provide modern data that may be useful as modern controls. The Sevilleta UNM Research Station has reports on excavations of several archaeological sites from Paleoindian to Pueblo periods.

Based on topographic features, reconnaissance was conducted in four primary areas of the Sevilleta (Figure 2):

1. Palo Duro arroyo and valle de la Joya off 5-points Road
2. San Lorenzo arroyo in the southwest Sevilleta towards West mesa
3. Sepultura Canyon
4. Tomasino Well-Cibola Spring region

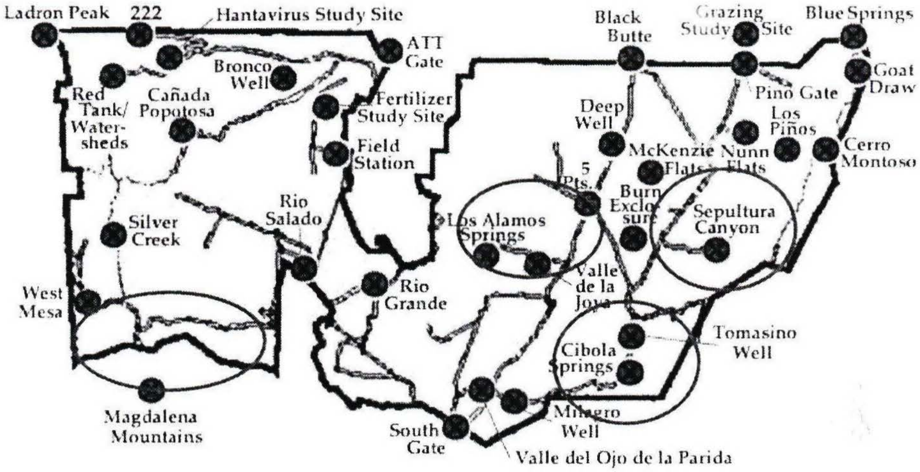


Figure 2: Sevilleta National Wildlife Reserve. Study areas mentioned in the text are circled in red. *Source:* LTER website (sev.lternet.edu/).

Early occupation of the Palo Duro is marked by a Paleoindian cave site located at the base of the modern arroyo floor. An additional series of caves is found approximately 4 meters above the arroyo floor. These caves appear to have been used for grain storage and small maize cobs were eroding from them as were packrat middens. However, although investigated in detail, the Palo Duro canyon walls appear to have a poor palaeoenvironmental record as no visible stratigraphy is present. The hillsides above the arroyo are actively eroding and unstable. No undisturbed sequences of burning or stabilization were identified.

The San Lorenzo region was also found to be unsuitable for palaeoenvironmental sampling. This area has been recently disturbed was as seen in garbage, power lines, cattle and fencing. The San Lorenzo drainage narrows heading southwest from Highway 24 and the arroyo walls composed are largely exposed bedrock rather than sediments and soils.

However, along the arroyo bottom between rock outcrops are stands of scrub live oak with protected floral communities beneath them which may be useful for comparative botanical analyses (Fig.3). These relatively moist microclimates appear to act like refuges of high biodiversity in an otherwise monotonous region of the Sevilleta.

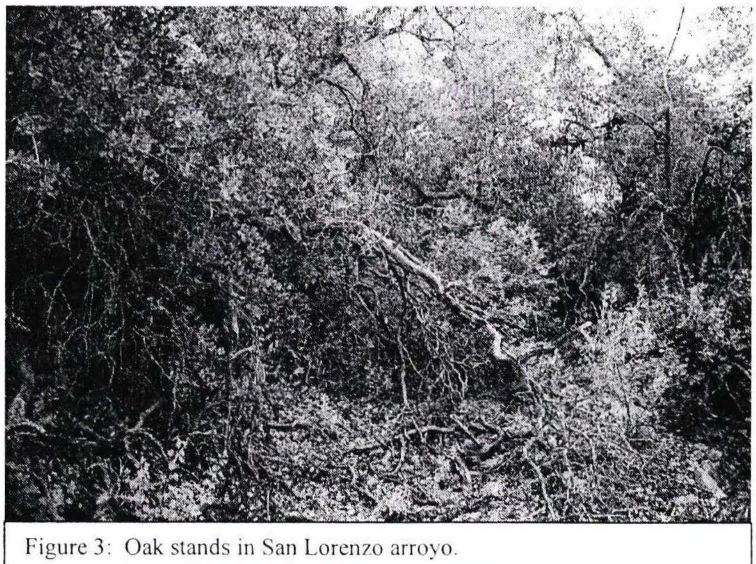


Figure 3: Oak stands in San Lorenzo arroyo.

The Sepultura canyon area is characterized by a red, sandy soil with sparse vegetation and frequent rock outcrops. This area size above the valley floor and is cut by a few arroyos. Several tributaries were investigated for intact stratigraphy but all were homogenized and unsuitable for sampling.

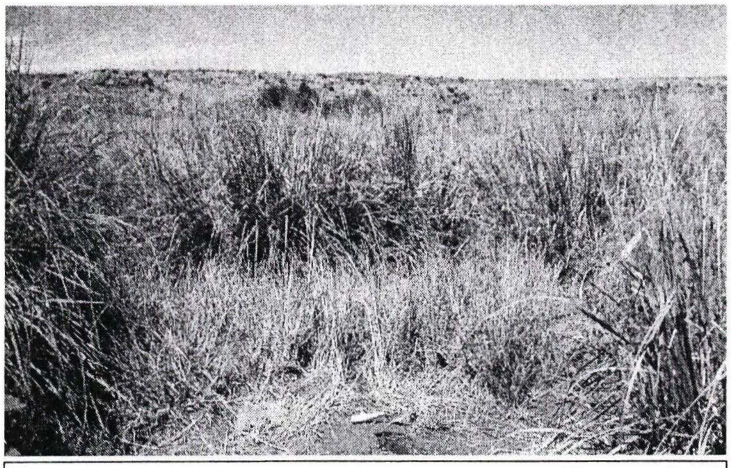


Figure 4: Sevilleta: Tomasino auger site with dense vegetation

The Tomasino Well-Cibola Spring area of the Sevilleta was more promising. A small valley intersects the Cibola Spring arroyo near the natural spring head. In June, this valley supported more luxuriant flora in low-lying areas than elsewhere in the Sevilleta (Fig. 4) and indeed the greater central New Mexico region. This may be partly attributed to the presence of the spring which runs across bedrock and apparently seeps down the valley as evidenced by the success of a modern well approximately 2 km down the valley. Although there is a small abandoned farmhouse, the relatively high density and number of plant species suggest that this area was also protected from overgrazing.

In order to characterize the deposits in this area, the valley bottom and surrounding hillsides were waked and Cibola Springs was located and investigated. The question arose as to the composition of valley deposits, their variability and the possibility of paleo-landscapes beneath them. A preliminary assessment was made by auger-coring the valley bottom at approximately 0.5 km intervals in three transects. In each transects, three auger holes were made and identified by GPS for a total of nine collection points (Appendix 1). Samples were described in the field and collected for bulk analyses.

Soil depth varied between 30cm and over 200cm. Bulk samples were collected at roughly 10 cm intervals for botanical and soil analyses. In the field, these soils appeared relatively uniform in color and texture suggesting thorough mixing through bioturbation. Surface bioturbation is unsurprising given the lush surface vegetation and it is notable that these deposits were relatively undifferentiated through their depths. Bulk analyses of these deposits including particle size analysis and organic matter determination may reveal differences obscured under field conditions.

This high degree of uniformity made the discovery of very well preserved stratigraphy in the arroyo that emerges from the Cibola Spring remarkable. Cibola Spring lies at the southern end of the augered area and a section of arroyo wall extends approximately 350m from the rocky Cibola Spring head before rising up to the modern valley floor. Observation of this arroyo revealed complex undisturbed stratigraphy (figure in

Appendix 2). This wall records a sequence of burns and standstill events which are similar to those observed in the Rio Puerco.

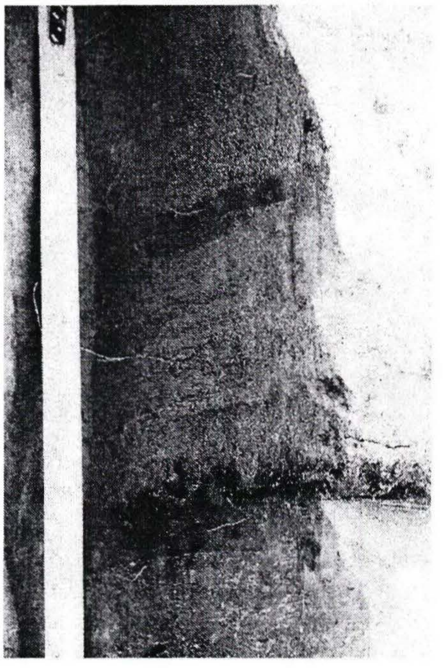


Figure 5: Cibola Spring arroyo soil micromorphology column detail. scale 20 cm

The Cibola Springs arroyo profile had up to three meters of undisturbed stratigraphy as described in Appendix 1. Below the modern surface is an upper standstill zone that lies on a gravel paleochannel. A second standstill zone lien beneath this, which . is composed of yellowish silty sands with incomplete gravel band of gravel. Charcoal appears at 60 cm from the surface a burn sequence was encountered with fine lenses and a possible iron pan between 74-77 cm (soil micromorphology samples 5 and 6).

A sequence laminated deposits of gravel, clay, silty sand, clay and caliche follow the first burn. At approximately 130 cm lay a second burn sequence (soil micromorphology samples 10 and 11). Ashy, rubified soil is found at 116 cm wfolllowed byy fine lenses and another charcoal-rich burning event (Fig. 5). This sequence of fine laminae repeats and a further burn sequence was encountered at approximately 198 cm from the surface (soil micromorphology samples 12 and 13).

Excavation of the block samples from the Cibola Spring arroyo revealed outstanding preservation where the placement of burning events within sequences of fine lenses of various textures suggest a close record of incremental erosion and standstills (Fig. 5). Block samples for soil micromorphology were collected at intervals down this arroyo wall. Sampling was discontinuous due to undulations of the deposits and accessibility along the wall. Eight block samples from the Sevilleta Cibola Spring arroyo profile were submitted to Spectrum Petrographics for processing into soil thin sections and will analyzed by Goodman-Elgar at Washington State University.

The presence of three well preserved erosion/standstill/burn events is strikingly similar to those observed in Rio Puerco. However, in the Sevilleta these events are much closer together. Radiocarbon dating will revel if this is due to increased fire frequency or less deposition between events. The preservation of fine laminae will aid in the understanding of how fire impacts sedimentation in the standstill zones.

Cibola National Forest Magdalena District

Investigations in the Cibola National Forest Magdalena District concentrated on the region surrounding a large Pueblo period site with over 500 stone masonry rooms which reflects Ancestral Pueblo and Mogollon influences (Tainter 2004 pers. com.). This is located along an arroyo named after a local windmill pump site Gallinas Spring (Fig. 6).

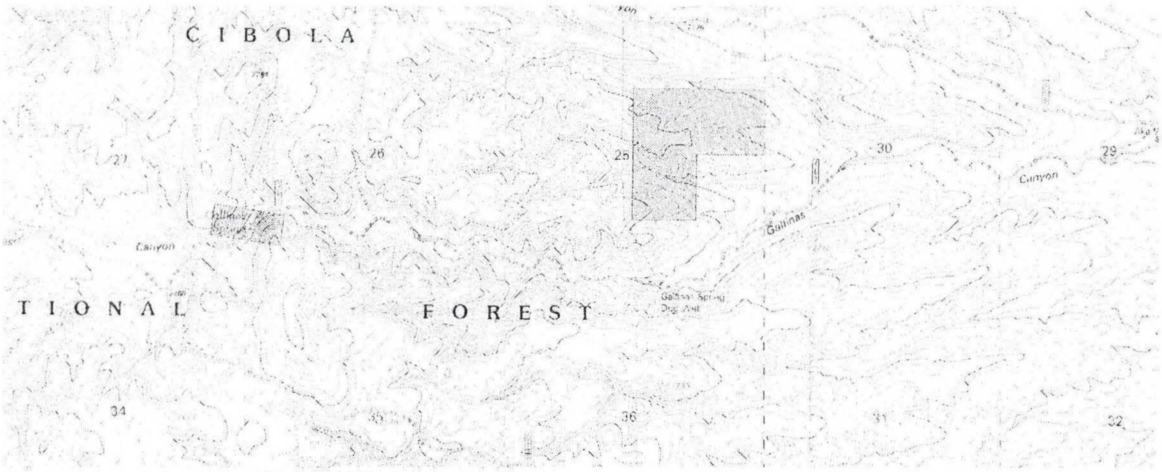


Figure 6: Cibola Magdalena District USGS Gallinas Spring Quandrange 7.5 minute map detail; Study area along arroyo and surrounding hillsides.

The modern vegetation in this region is a sparse pine forest with patches of meadow grassland which reflects the elevation, around 7000 ft, and dry conditions. The topography rises to the west and drops to the east along the main arroyo. Deep topsoils appear intermittently in the arroyo cut and may continue across low-lying unforested areas. Frequent rock outcrops break up the sediments in the arroyo wall indicating that the bedrock is uneven and making for a dissected topography. The Magdalena Gallinas Spring Arroyo cut has sections with thick layers of sorted cobbles providing evidence for incision and channel fill. In other locations, a detailed stratigraphy is preserved in the arroyo walls indicating that this area has also experienced a series of burning events.

The standing architecture of the Pueblo period site includes a dense settlement with rectilinear dwellings, round storerooms and larger kiva-style rooms to the south of the arroyo. Dense architecture continues on the north side of the arroyo and includes dwellings and a stone-lined channel. The Magdalena Gallinas Spring Arroyo is cut by another arroyo running roughly north-south. Across this arroyo, to the east of the main site, is another complex of dispersed structures that appear related to the pueblo (Tainter 2004 pers. comm.).

The downhill areas surrounding these archaeological remains are unusually flat and the surface supports dense grasses. The arroyo cut reveals exceptionally deep, dark brown top soil in comparison to the natural forest brown earth profile (Fig.7). Below the topsoil is a darker gray-black soil that grades into the arroyo incision and refill sequence. Due to the proximity of the archaeological Pueblo period sites, these flat areas look suspiciously like amended agricultural fields. Preliminary samples from the arroyo cut adjacent the south part of the site were collected.

The natural catena was investigated along the arroyos above the archaeological site by recording a series of soil profiles. Profile locations were identified by using a GPS and

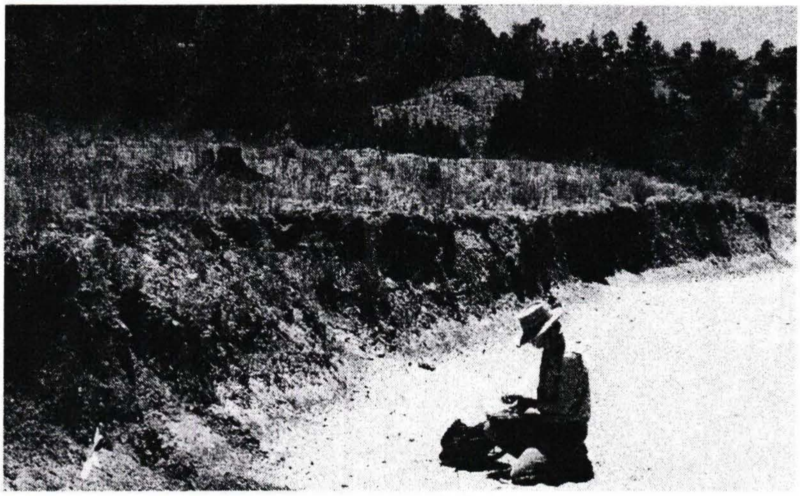


Figure 7 Sampling the "field " adjacent Pueblo site in the Cibola-Magdalena

described (Appendix 2). One soil profile within the forest catena was collected as a control for the burn sequences found further downhill.

About one mile east of the Pueblo site lies a section of preserved stratigraphy in the arroyo wall (Appendix 2). This section contains several distinct charcoal-rich layers which start as spongy ashy deposits and become well defined strata of carbon and ash elsewhere in the sequence. The well-preserved deposits extend over 2m deep and this profile was sampled for block and bulk samples. The surface is ponderosa pine forest and woody roots extend intermittently down the profile. Charcoal and ash deposits are found from 50cm and include both distinct carbon bands and ephemeral ash layers which continue to the lowest deposits (Fig. 8).

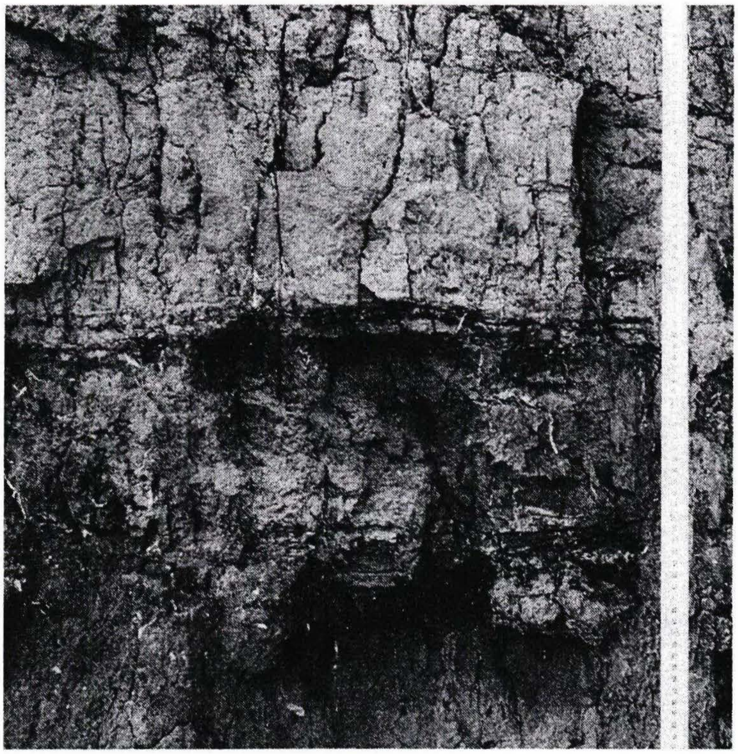


Figure 8: Detail of ash and charcoal rich strata in Cibola-Magdalena block sample column (scale 50 cm).

The presence of deep topsoils by the archaeological site and fire sequences some distance away suggest that there may be a relationship between fire induced soil conditions and the settlement. One hypothesis for selection of the Pueblo site would be that the sequence of fairly frequent fires released considerable nutrients into the soil that were exploited near the spring for agriculture. This use, possibly augmented by household midden, could produce the deeper topsoil observed by the site. Radiocarbon dates from the fire sequence coupled with analyses of the field sample will help assess this hypothesis.

Reconnaissance in Montana

The focus of investigations in Montana centered in the forests around Missoula. Reconnaissance areas included Mary's Frog Pond, Packers' Meadows, Kaiser Lake and Copper Creek, where preliminary core samples were taken (French 2004). During September, 2004 two additional regions were investigated: the Swan Valley and additional locations in the Deerlodge National Forest. Thick peat deposits suitable for palaeoenvironmental coring were identified in both regions by probing to identify the extent and depth of peat deposits.

Swan Valley
About 25 miles north of Seeley Lake on MT83 near Condon lie several lakes and wetlands. The topography is highly irregular and undulating, which does not favor deep peat deposits in many areas.

On County Road 903 (Cold Creek Road) toward Cold Lakes there are several small unnamed lakes which do not support deep peat deposits. However, investigations of Peck Lake, on a marked turnoff from Forest Road 888, were more promising. A probed transect toward Peck Lake revealed wet peat deposits to about 150cm. A dry bog along Peck Lake Road also had peat deposits to about 30cm. There are undoubtedly other peat deposits in this region but further investigation will require dry road conditions and 4WD as the logging-style road is undeveloped.

Deerlodge National Forest
Following the Skalkaho Road west of Copper Creek/Moose Lake on MT38 towards Skalkaho Falls are several additional wetlands with peat deposits. The most promising of these surround Mud Lake (T6N, R17W, 32) (Fig. 8). This small lake sits below a scree hillside and is surrounded by a flat bog with low grass over sphagnum moss which covers an area larger than the lake itself. Standing vegetation include stands of spruce and pine. An extensive burn appears to have occurred recently to the west and south of the lake and many standing trees are burned.

Figure 8: Probing peat deposits in Mud Lake, Deerlodge National Forest

A transect from the bog edge to the lake edge reveals peat from 25cm at the bog edge to over 150cm. The lake has been developed for fishing and a wooden trackway extends to the lake edge (Fig. 8). A transect along this track at 10 m intervals shows considerable peat deposits from 110cm at 15m from the bog edge to 150cm at 25m and well over 170 at 35m along the track toward the lake edge. The wooden track could provide s

platform for sampling using a corer.

Another unnamed wetland to the north of the Skalkaho Road near the exit to road 5029 had the peat depths at right:

Distance from road (m)	Depth (cm)
10	50
20	65
30	30
40	20
55	40
65	25
75	10

This bog has a running stream with meanders. It may provide a useful comparison to Mud Lake if a sequence of closely spaced bogs were desirable to test regional patterns.

Heading south along Sand Basin Road from Skalkaho Road Junction are another set of peat wetlands and meadows. The wetland areas in this area are densely vegetated on the northern reaches of the road. Moving south towards Medicine Lake the topography rises and level areas have peat deposits

The furthest point we reached was T5N R16W 35, which had a promising peat bog. Two transects were probed as detailed below

Transect 1		Transect 2	
Distance from road (m)	Depth (cm)	Distance from road (m)	Depth (cm)
0	20	0	30
20	30	5	70
30	40	20	20
44	15	30	100
		40	30

Further investigations of peat depths were curtailed by the loss of our probe. However, T5N R16W 24-25, to the west of the road contained a large meadow with a meander stream and some shallow peat formation. In addition, meadows without peat are found to the north and a possible peat bog is found at the junction of West Fork Road and Sand Basin Road TN5 R17W 11.

Overall, the potential for peat sampling in the region surrounding Missoula, Montana is excellent. Several regions to the north and southeast of Missoula contain extended peat bogs with deposits of considerable depth. Preliminary sampling of deposits in Copper Creek indicated that preservation can be excellent and that charcoal residues may be well preserved.

Summary of 2004 Field Investigations

Investigations in New Mexico identified paleosol sequences demonstrating that the sequences of erosion, stability and burning found in the Rio Puerco may be widespread throughout central New Mexico. Further reconnaissance of the Rio Puerco identified additional sampling locations with a longer preserved history, possibly into the Paleoindian periods. Future core drilling in this area may be the best means to collect uncontaminated material for dating, pollen and other environmental work. Judgmental sampling for bulk soil micromorphology samples along the unnamed arroyo described above would provide stratigraphic control and the potential for high resolution thin section analyses.

Investigations in the Sevilleta Cibola Spring arroyo revealed sequences of erosion, standstill and burning that are remarkably similar to those encountered in the Rio Puerco region. Analyses of eight thin section, bulk samples and radiocarbon dating will provide a comparison to the Rio Puerco which will help indicate if the periodicity of burning bears similarity between these regions. It is recommended that basal dates be acquired for the valley bottom. Pollen and environmental analysis should concentrate on a subset from both surface and deep samples for preliminary assessment.

The Gallinas Spring arroyo of the Cibola National Forest Magdalena District also revealed the potential for arroyo stratigraphy in palaeoenvironmental and fire frequency reconstruction in central New Mexico. In this area, the charcoal-rich layers appear at a much greater frequency which may reflect increased frequency of burning within the forest environment or perhaps reflect secondary deposition of burned materials. Radiocarbon dating and analysis of thin sections from this profile will shed light on these and other issues as well as help relate the Cibola profile to other study areas in New Mexico.

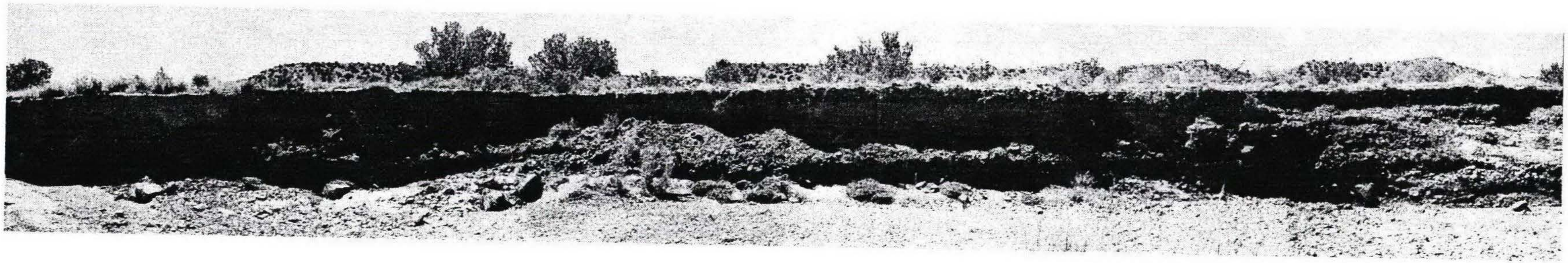
In Montana, the outcome of the 2004 investigations was also very promising. If permission is granted from the regional Forest Service Districts, coring at sites such as Kaiser Lake, Mud Lake and along the Skalkaho Road could be swiftly accomplished during future seasons. The analytical methodology is flexible enough to encompass the very different modern landscapes of Montana and New Mexico providing a framework for further investigations that would eventually begin to link patterns of fire frequency and anthropogenic influence within the greater Rocky Mountain region.

Reference

French, C.A.I. 2004. Long-term landscape and fire history of riparian areas of northern New Mexico and western Montana: Phase 1 interim report 1.

Appendix 1

Sevilleta Cibola Spring Profile



Sevilleta Samples

Area	Site	Transect	Profile	Sample	C14	Soil	Paleo	Process	
Sevilleta	Tomasino	TR1	PR1	A		1	1	1	
Sevilleta	Tomasino	TR1	PR1	B	1	1	1		
Sevilleta	Tomasino	TR1	PR1	C		1	1		
Sevilleta	Tomasino	TR1	PR1	D		1	1		
Sevilleta	Tomasino	TR1	PR1	E		1	1		
Sevilleta	Tomasino	TR1	PR1	F		1	1		
Sevilleta	Tomasino	TR1	PR1	G		1	1		
Sevilleta	Tomasino	TR1	PR1	H		1	1		
Sevilleta	Tomasino	TR1	PR1	I	1	1	1	1	
Sevilleta	Tomasino	TR1	PR1	J		1	1		
Sevilleta	Tomasino	TR1	PR1	K		1	1		
Sevilleta	Tomasino	TR1	PR1	L		1	1		
Sevilleta	Tomasino	TR1	PR1	M		1	1		
Sevilleta	Tomasino	TR1	PR1	N	1	1	1	1	
Sevilleta	Tomasino	TR1	PR1	O		1	1		
Sevilleta	Tomasino	TR1	PR1	P		1	1		
Sevilleta	Tomasino	TR1	PR1	Q		1	1		
Sevilleta	Tomasino	TR1	PR1	R		1	1		
Sevilleta	Tomasino	TR1	PR1	S		1	1		
Sevilleta	Tomasino	TR1	PR1	T		1	1		
Sevilleta	Tomasino	TR1	PR1	U	1	1	1	1	
Sevilleta	Tomasino	TR1	PR1	V		1	1		
Sevilleta	Tomasino	TR1	PR2	A		1	1	1	
Sevilleta	Tomasino	TR1	PR2	B		1	1		
Sevilleta	Tomasino	TR1	PR2	C		1	1		
Sevilleta	Tomasino	TR1	PR2	D		1	1	1	
Sevilleta	Tomasino	TR1	PR3	A		1	1	1	
Sevilleta	Tomasino	TR1	PR3	B		1	1		
Sevilleta	Tomasino	TR1	PR3	C		1	1		
Sevilleta	Tomasino	TR1	PR3	D		1	1	1	
Sevilleta	Tomasino	TR1	PR3	E		1	1		
Sevilleta	Tomasino	TR1	PR3	F		1	1	1	
Sevilleta	Tomasino	TR1	PR4	A		1	1	1	
Sevilleta	Tomasino	TR1	PR4	B		1	1		
Sevilleta	Tomasino	TR1	PR4	C		1	1		
Sevilleta	Tomasino	TR1	PR4	D		1	1		
Sevilleta	Tomasino	TR1	PR4	E		1	1	1	
Sevilleta	Tomasino	TR2	PR1	A		1	1	1	
Sevilleta	Tomasino	TR2	PR1	B		1	1		
Sevilleta	Tomasino	TR2	PR1	C		1	1	1	
Sevilleta	Tomasino	TR2	PR2	A		1	1	1	
Sevilleta	Tomasino	TR2	PR2	B		1	1		
Sevilleta	Tomasino	TR2	PR2	C		1	1		
Sevilleta	Tomasino	TR2	PR2	D		1	1		
Sevilleta	Tomasino	TR2	PR2	E		1	1	1	
Sevilleta	Tomasino	TR2	PR2	F		1	1		

Sevilleta Samples

Sevilleta	Tomasino	TR2	PR2	G		1	1		
Sevilleta	Tomasino	TR2	PR2	H		1	1		
Sevilleta	Tomasino	TR2	PR2	I		1	1		
Sevilleta	Tomasino	TR2	PR2	J		1	1	1	
Sevilleta	Tomasino	TR2	PR2	K		1	1		
Sevilleta	Tomasino	TR2	PR2	L		1	1		
Sevilleta	Tomasino	TR2	PR2	M		1	1		
Sevilleta	Tomasino	TR2	PR2	N		1	1	1	
Sevilleta	Tomasino	TR2	PR2	O		1	1		
Sevilleta	Tomasino	TR2	PR3	A		1	1	1	
Sevilleta	Tomasino	TR2	PR3	B		1	1		
Sevilleta	Tomasino	TR2	PR3	C		1	1		
Sevilleta	Tomasino	TR2	PR3	D		1	1		
Sevilleta	Tomasino	TR2	PR3	E		1	1	1	
Sevilleta	Tomasino	TR2	PR3	F		1	1		
Sevilleta	Tomasino	TR3	PR1	A		1	1	1	
Sevilleta	Tomasino	TR3	PR1	B		1	1		
Sevilleta	Tomasino	TR3	PR1	C		1	1		
Sevilleta	Tomasino	TR3	PR1	D		1	1		
Sevilleta	Tomasino	TR3	PR1	E		1	1	1	
Sevilleta	Tomasino	TR3	PR2	A		1	1	1	
Sevilleta	Tomasino	TR3	PR2	B		1	1		
Sevilleta	Tomasino	TR3	PR2	C		1	1		
Sevilleta	Tomasino	TR3	PR2	D		1	1		
Sevilleta	Tomasino	TR3	PR2	E		1	1		
Sevilleta	Tomasino	TR3	PR2	F		1	1	1	
Sevilleta	Tomasino	TR3	PR2	G		1	1		
Sevilleta	Tomasino	TR3	PR2	H		1	1		
Sevilleta	Tomasino	TR3	PR2	I		1	1	1	
Sevilleta	Tomasino	TR3	PR2	J		1	1		
									SMM
Sevilleta	Cibola Springs	TR4	PRA	SMM1	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM2	1	1	1	1	2
Sevilleta	Cibola Springs	TR4	PRA	SMM3	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM4		1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM5	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM6	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM7		1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM8		1	1	2	1
Sevilleta	Cibola Springs	TR4	PRA	SMM9		1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM10	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM11		1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM12	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM13	1	1	1	1	1
Sevilleta	Cibola Springs	TR4	PRA	SMM14		1	1	1	
Sevilleta	Cibola Springs	TR4	PRA	SMM15		1	1	1	
Sevilleta	Cibola Springs	TR4	PRA	SMM16	1	1	1	1	
					13	92	92	41	14

Sevilleta Soil Descriptions

Sevilleta Cibola Springs Augered transects

Note: Each augered sample is approximately 10 cm deep

Transect	Profile	Sample	Description
TR1	PR1	A	Red brown, moist, organic-rich. Silty clay; fine root <1%, no stone, charcoal or coarse organics
TR1	PR1	B	Red brown silty clay as above: v. fine flecks 1-2%, fine root <1%
TR1	PR1	C	As above but drier: worm, root 1%, white nodules <1% (root?)
TR1	PR1	D	As above: with root, black flecks (possible charcoal)
TR1	PR1	E	As above
TR1	PR1	F	As above: no charcoal, fine root <1%
TR1	PR1	G	As above: root 1%
TR1	PR1	H	As above: leaf fragments, organic matter, thicker root 1%
TR1	PR1	I	As above but wetter and slightly browner: some black flecks <1%
TR1	PR1	J	As above: root 1-2%
TR1	PR1	K	As above, fine root <1%, black flecks <1%, CaCO3 <1%
TR1	PR1	L	As above but drier: fine root 2%, white flecks <2% (calcite?)
TR1	PR1	M	Medium red brown silty clay, drier and siltier than above: fine root <1%, granite pebble <1%: harder to augur than above
TR1	PR1	N	As above but drier, slightly lighter more orange: fine root <1%, coarse sand: possibly finer than above
TR1	PR1	O	Light orange brown silty clay, siltier than above, dry: very fine root <1%, angular granite or basalt pebble
TR1	PR1	P	As above but pebbles <1%, dry, fine, soft - some sand
TR1	PR1	Q	As above but yellower, fewer roots and more pebble inclusions
TR1	PR1	R	As above but finer and drier: fine root <1%
TR1	PR1	S	As above
TR1	PR1	T	As above
TR1	PR1	U	Yellow brown, very fine silty clay, dry, root <1%
TR1	PR1	V	As above with <1% sub angular pebbles
TR1	PR2	A	Dry orange brown silty clay: root <2%, sub angular pebbles 2-3cm, 4%, fine mica inclusions
TR1	PR2	B	As above but slightly lighter: root <2%, pebbles 1-4cm 5%
TR1	PR2	C	As above: pebbles 7%, some saprolite, fine root <2%
TR1	PR2	D	Yellow brown silty clay: sub angular pebbles 13%: fine root
TR1	PR3	A	Moist red brown silty clay with some ash, soft and loose: fine root < 5%. Sub angular pebble 1-3cm <1%, black flecks <1%
TR1	PR3	B	As above but less ash, fine root <1%, small pebbles 2%
TR1	PR3	C	As above but moister and redder. Fine root <1%. Sub angular pebbles 2-3%, black flecks <1%
TR1	PR3	D	As above but slightly drier: smaller and fewer pebble inclusions 0-1cm, 2%, black flecks <<1%
TR1	PR3	E	As above but drier and lighter: fine root, sub angular pebbles 0-2cm <1%. No carbon
TR1	PR3	F	As above but powdery coming down on what feels like rock
TR1	PR4	A	Damp loose red brown silty clay, root <1%, SAP 0-2cm <1%, trace of ash

Sevilleta Soil Descriptions

TR1	PR4	B	As above but more compact and moister, no ash, root and SAP as above
TR1	PR4	C	Light red brown silty clay, finer and looser than above, root <1%, small SAP 1-2%: feels less claylike
TR1	PR4	D	Same as above: fine root <1%, small white friable SAP 0-3cm 2-3% (granite and calcite?)
TR1	PR4	E	As above but drier: SAP increase to 5-6%
TR2	PR1	A	Slightly damp, red brown soft silty clay: root <1%, sub angular pebbles 0-2cm, 2-3%
TR2	PR1	B	As above but sandier: root <1%, sub angular pebbles 0-4cm, 3-4%
TR2	PR1	C	As above but more compact and coarser, some saprolite
TR2	PR2	A	Dry, red brown silty clay, loam, loose: fine root <1%, SAP 0-2cm, 2-3%
TR2	PR2	B	As above - root <1%, SAP as above: feels sandier and finer than above
TR2	PR2	C	As above but lighter in color: root <1%, pebbles 1-2%: texture clods in unconsolidated matrix: possibly coarser than above
TR2	PR2	D	As above but possibly coarser. Pebbles 2-3%
TR2	PR2	E	As above but yellower. Root <1%, Pebbles 2-3%: clods in fine material as above
TR2	PR2	F	As above but possibly finer
TR2	PR2	G	As above but more sand and less consolidated: possible saprolite
TR2	PR2	H	As above, root <1%
TR2	PR2	I	As above
TR2	PR2	J	As above but darker red: some dark inclusions <1% possibly Mg from saprolite
TR2	PR2	K	As above
TR2	PR2	L	As above but fewer roots
TR2	PR2	M	As above but no roots
TR2	PR2	N	As above
TR2	PR2	O	As above but sandier, saprolite 2%
TR2	PR3	A	Fine light reddish brown silty clay: root 2%
TR2	PR3	B	As above
TR2	PR3	C	As above but SAP 1-5cm 3% granite with quartz
TR2	PR3	D	As above: root 1-2%, SAP as above but smaller
TR2	PR3	E	As above: with crumbly white pebbles possibly carbonate
TR2	PR3	F	As above but slightly redder, pebbles larger to 5cm 5%, carbonate as above
TR3	PR1	A	Medium red brown silty clay: root <1%, pebbles 3%
TR3	PR1	B	As above but pebbles 5%
TR3	PR1	C	As above but lighter with some grey: larger pebbles to 10%: some saprolite; calcite and quartz?
TR3	PR1	D	As above: root <1% and organic fragments possible bark, SAP 0-5cm 10% granite quartz finer than above
TR3	PR1	E	As above but lighter grey-red brown, fine root <1%, less pebble carbonate 1-2%
TR3	PR2	A	Damp yellow-orange brown silty clay, root 1-2%
TR3	PR2	B	As above but browner and fewer roots <1%

Sevilleta Soil Descriptions

TR3	PR2	C	As above but fewer roots <<1%, pebble 1% white rock as TR3 PR1
TR3	PR2	D	As above but yellower, some clods, root <<1%, pebbles 0-2cm <1%
TR3	PR2	E	As above but finer and lighter, very few roots, pebble <1%
TR3	PR2	F	As above but finer and smaller clods
TR3	PR2	G	As above
TR3	PR2	H	As above
TR3	PR2	I	As above but pebbles <1%
TR3	PR2	J	As above but pebbles 2% 1-4cm

Sevilleta Soil Descriptions

Cibola Springs Soil Micromorphology Profile				
Transect	Profile	Sample	Description	Depth (cm)
TR4	PRA	surface	mixed vegetation including juniper, holly, grasses, cholla and Russian willow	0
TR4	PRA		silty clay with abundant carbonate infilled channels and fine root 5%; amorphous carbonate (sample - insecure); spongy with 2% open pores (insect burrows?); medium red brown	15
TR4	PRA		more compact and lower porosity; yellow-brown; fine root 1% but no other inclusions	20
TR4	PRA		discontinuous 1cm thick iron pan	25
TR4	PRA		yellow brown silty sand until 1 cm carbon rich lens at 30 cm, which appears to represent an in situ burn	30
TR4	PRA		undulating sorted gravel paleochannel	52
TR4	PRA	SMM 3	fine silty clay with abundant calcareous infilled channels; flecks of carbon and some sandy pockets, which may be infilled insect burrows.	60
TR4	PRA	SMM 4	dense yellow silty clay in size-sorted laminations	71
TR4	PRA	SMM 5	sequence broken by a possibly iron pan (1 cm) and them dense yellow silty clay with a sharp boundary becoming rubified (1 cm)	74
TR4	PRA	SMM6	charcoal rich burning event	77
TR4	PRA	SMM6 & 7	consolidated carbonate rich medium red-brown silty clay, fine pores 5%	85
TR4	PRA		gravel band with some larger clasts	88
TR4	PRA	SMM8	Laminations of hard, dry consolidated yellow clay, red porous calcium carbonate rich silty clay and caliche (as above)	102
TR4	PRA	SMM9	Silty dense yellow clay	108
TR4	PRA	SMM9	spongy ashy rubified silty clay with carbon 1-4mm (7%), calcium carbonate <1mm (30%) pebbles and green saprolite 5-10mm (5%); fine to medium root 2%	116
TR4	PRA		dense light brown silty clay	130
TR4	PRA	SMM 10	porous red -brown silty clay with abundant carbonate inclusions	145
TR4	PRA	SMM 10 & 11	sharp boundary black burning event	148
TR4	PRA	SMM 11	porous red brown silty loam with carbonate flecks as above	166
TR4	PRA		undulating caliche band	167
TR4	PRA		poorly consolidated sandy loam with some clay inclusions, rounded pebbles to 20%	183
TR4	PRA	SMM 12	soft, moist, sandy loam root 2%, cobbles with thick carbonate coats	
TR4	PRA	SMM 12	dense black carbon lens with charcoal to 3mm	198
TR4	PRA	SMM 13 & 14	graded silty and silty clay with fine root 1%, white flecks 5-10%, containing a second thinner black lens at 202cm; SMM 14 at the base of this sequence	218
TR4	PRA		unsorted pea gravel and pebbles with little fine material	223

Sevilleta Soil Descriptions

TR4	PRA	SMM 15	graded silty laminations as above with thin gravel bands	234
TR4	PRA	SMM 16	as above but contains rare pieces of black charcoal to 1 cm and then grades into crumbling gravel of bedrock	245
Discontinuous sequence taken at a different location on the profile				
TR4	PRA	SMM 2 A	lower channel infill of subangular to subrounded cobbles, gravel and pebbles in a sorted sandy clay matrix; the clay appears to concentrate between the larger clasts with caliche on top of clay aggregates; the texture is like friable mudstone; this sample appears similar to the modern surface of the arroyo and the paleochannel may have had a similar orientation; rare carbon embedded in rock (Sample)	145
TR4	PRA	SMM 2B	poorly consolidated unsorted subrounded gravel band embedded in silty sand; this band appears to continue along the entire exposed arroyo ca. 50 m	148
TR4	PRA	SMM1	lower stand still zone in a small exposed section protected by gravel of overlying paleochannel; silty clay loam with very fine sand with incomplete laminae; soil was moist from recent rain and friable; although compact it is riddled with 0.5-2mm channels many of which appear to have been infilled with carbonates; subrounded platy rock inclusions s5%; some calcareous saprolite and rare granite inclusions; rare black inclusions<1%; occasional visible charcoal (sampled; however, caliche appears to be cementing part of this layer)	180 cm
TR4	PRA		bedrock in arroyo bottom is red slate fractured in trapezoidal pattern in plates 1-5 cm in thickness that is interbedded with crystalline veins and streaks of grey/green/white granite to 5%	

Sevilleta 2004 Samples

Thin section samples sent to Spectrum Petrographics

Sevilleta	Cibola Springs	TR4	PRA	SMM1
Sevilleta	Cibola Springs	TR4	PRA	SMM5
Sevilleta	Cibola Springs	TR4	PRA	SMM6
Sevilleta	Cibola Springs	TR4	PRA	SMM7
Sevilleta	Cibola Springs	TR4	PRA	SMM9
Sevilleta	Cibola Springs	TR4	PRA	SMM10
Sevilleta	Cibola Springs	TR4	PRA	SMM11
Sevilleta	Cibola Springs	TR4	PRA	SMM13

Gallinas Spring Reconnaissance

Profile	depth	description
WP 1	0-20	burnt wood and exposed soil, undulating surface
	129	variable concentrations of subterranean burnt wood and woody root in light brown silty sand with unsorted oriented subangular gravels to 15%; woody root >1%.
	160	undulating boundary; banded subangular gravel in irregular bands with woody root to 1% in an undifferentiated silty sand matrix; grades into cryptocrystalline sesquioixe-rich bedrock
WP2	surface	ponderosa pine, juniper and sparse grass
	0-2	sparse leaf litter
	2-150	medium brown, silty sand with 50% subangualr fine gravel that grades into inerbedded laminations of very coarse sand and gravels (70%); Soil grades to medium dark brown and appears enriched by sesquioxides from decaying bedrock
		bedrock
WP3	surface	ponderosa pine, juniper and sparse grass
	0-3	
	20	Medium brown silty sand with abundant woody root
	120	undulating boundary; lighter brown silty sand with unsorted subangular gravels to 50%; woody root declines down the profile
	180	Finer medium light brown silty clay loam, with 20% gravel as above including saprolites; no root; grades into crumbling bedrock
		bedrock
WP4	surface	grasses including amaranthus, juniper, rabbit bush, sage, poaceae (no leaf litter)
	0-20	medium brown silty loam interbedded with subangular very coarse sand that contains gravel inclusions; >1% fine root
	100	as above with silty lenses of very coarse sand and fine sand; undulating boundary; white carbonate infilled microrrhizae channels
	130	as above but darker brown and friable without sandy lenses
	133	light yellow carbonate-rich band; sharp boundaries; >1% fine root.
	148	medium brown silty loam with sesquioxide mottling
	165	undulating boundary; mixed macro charcoal to 2mm in dark brown silty loam, less sesquioxide mottling than above; no visible rock or root
	200	grades to sandstone
		*This sequence appears to be the result of washed in burn debris from a different location
WP5	surface	dense grasses
	20	powdery medium brown silty loam, sounded and subangular very coarse sand and gravels very dense fine root

	47	as above but roots degrease with depth
	62	caliche with some pea gravel
	76	dark brown silty clay loam with carbonate infilled channels; no root or gravel
	85	bedrock is degrading yellow brown sandstone with gravel
		Forest natural (sampled)
WP8	0-4	dense pine needle O horizon
	10	sharp boundary, light brown sandy loam; root to 10%
	30	grades darker with what appears to be inclusions of burnt earth and ashy subangular fine gravel 5%
	60	as above but contains thick tree root and finer root to 15%
		grades back to light brown as above
	80	as above but increasingly sandy and friable; grades lighter with less apparent organic content; increase in fine gravel; decrease in porosity to become slightly consolidated
		undulating boundary; as above but darker and redder (appears to come from saprolitic gravel below)
	120	sharp boundary; horizontally oriented lenses of subangular sand and gravel; bands are weakly sorted; no root, very low porosity
	176	sharp boundary; discontinuous silty laminations with dark grey upper boundaries (difficult to ascertain if organic, charcoal or manganese) interbedded with coarser bands; woody root to 10%
		Laminations about 1-2mm; sandy bands 2-55 mm; there appear to be at least 8
	190	undulating boundary; pea gravel and coarser rock in dark very coarse sand; massive
		Fire sequence (sampled)
WP9	0-4	ponderosa pine with needle leaf little O horizon
	25	undulating boundary; gravelly medium brown A
	28	as above but increase concentration of fine root to 10%
	42	as above but decreased root and increased unsorted gravel
	49	medium grey-brown silty sand (possibly ashy) with lenses of very coarse sand
	50	dark carbonate lenses disturbed by thick woody root
	60	medium grey-brown silty sand with flecks of charcoal and ephemeral lenses
	61	ephemeral charcoal layers
	78	charcoal -rich silty sand as above
	80	second thick carbon band with visible charcoal
	99	lighter silty sand than above with a discontinuous charcoal band at 99 cm
	105	third carbon band
	107	silty sand as above
	109	fourth carbon band
	110	grey-brown silty sand with visible charcoal flecks; vertical calcium carbonate infilled channels
	112	spongy ashy-carbon layer that is much more porous than above and is speckled with calcium carbonate

	119	silty sand as above with carbonate channels as above and some root pipes; grades lights
	131	less charcoal going down the profile
	160	as above but soil is moister
	190	undulating dark (carbon?) lenses intergraded with fine yellowish sand that is mottled with sesquioxides
	220	granite cobbles in yellow sand